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Role and contribution of the clean development mechanism to the development of wind energy

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ABSTRACT

The world driven by the concern for climate change and by growing prices for fossil fuels is trying to make a more drastic shift towards renewable energy sources (RES). The Kyoto Protocol mechanisms are considered to assist this process in both developed and developing countries. The scope of this paper is to analyze the so far gained experience by the implementation of the clean development mechanism (CDM), in order to investigate its role in the formation of wind energy markets in developing countries. For this purpose we make a brief overview of existing incentives for the RES support within hosting countries. Then, we exploit the available CDM databases in order to identify the influence of CDM activities on the development of the corresponding wind energy markets.

Contents

1. Introduction

Increasing energy demand in developing countries is the obvious consequence of their economic development and a major challenge for the whole world since the energy sector is the largest emitter of CO_2, which is the main greenhouse gas (GHG). Concerns about climate change are pushing towards the development of renewable energy sources (RES) technologies. Among the most fast growing RES technologies is wind power, a massive indigenous power source, which is available virtually in every part of the world. Wind power is already a mature technology, and, in some cases (windy sites), even competitive with conventional power generation technologies, in particular when taking into account the growing prices for fossil fuels and the expenses for environmental issues. Modern wind turbines exhibit a high improvement of power rating, efficiency and reliability. Generation costs per kWh produced from wind have been falling over the last 15 years, approaching the cost of conventional energy sources [1].

Over the past ten years, the global wind power capacity was steadily growing with an annual rate of around 30%. In 2009, the installed capacity reached around 160 GW (Fig. 1). This growth is

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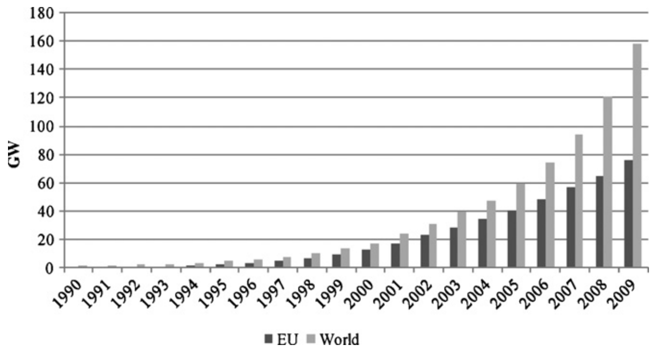


Fig. 1. Growth in wind energy installed capacity in world and EU [1].

Table 1
Total and top 10 wind energy capacity for 2009 [1].

Country	MW	%
USA	35,064	22.1
China	25,805	16.3
Germany	25,777	16.3
Spain	19,149	12.1
India	10,926	6.9
Italy	4850	3.1
France	4492	2.8
UK	4051	2.6
Portugal	3535	2.2
Denmark	3465	2.2
Rest of the world	21,391	13.5
Total top 10	137,114	86.5
World total	158,505	100.0

being driven by a number of factors, including the high rates of global energy demand, the rising concern for various environmental issues with the emphasis on climate change, and the impressive improvements in the technology itself. Wind energy has grown into an important player in the world's energy markets, with the 2009 market for turbine installations worth amounting at about 63 bn US$ or 45 bn € [1].

The global wind energy development is mainly concentrated in three key regions: Europe, Asia and North America. The share of the major countries to the total installed capacity is shown in Table 1. Note that among the top countries are China and India, holding an aggregate share of around 23%.

2. CDM and wind energy generation

The Kyoto Protocol, an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC) [2], sets binding targets for 37 industrialized countries for reducing GHG emissions. Simultaneously, the Kyoto Protocol provides the possibility to Annex-I countries to reach part of their target through three types of flexible mechanisms to reduce GHG emissions: *joint implementation* (JI), *clean development mechanism* (CDM) and *international emission trading* (IET).

CDM gives the possibility to developed countries to receive credits from relatively low-cost emissions reductions. Actually, achieved reductions are translated into *Certified Emission Reductions* – CERs, and every credit amounts to 1 ton of CO_2 equivalent. A CER can be freely traded on international carbon market and be used by developed country Governments and companies to meet their reduction commitments under the Kyoto Protocol.

At the same time, CDM projects are expected to assist developing countries in reaching sustainable development objectives. A multiplicity of economic, social and environmental aspects, such as the transfer of technology and financial resources, the improvement of energy efficiency, the introduction and promotion of sustainable ways of energy production, the generation of working places, the improvement of local environment and poverty alleviation are among the main benefits that are associated with CDM activities [3].

According to the adopted rules, a set of requirements must be met so that a project is registered as a CDM activity. One of the most important requirements is "additionality", i.e. the condition that the greenhouse gas emissions after the implementation of a CDM project activity are lower than those that would have occurred in the most plausible alternative scenario to the implementation of the CDM project activity. Proving additionality becomes harder when forward-looking governments in developing countries introduce incentives to support the process of decarbonisation of the electricity sector.

RES constitute an important part of CDM activities. The RES projects in the CDM pipeline are presented in Table 2, classified by type of energy source and by their position in the pipeline. By pipeline we mean the whole process of projects registration and tracking starting from the day of submission to the UNFCCC Secretariat. The CDM pipeline contains projects under review and already registered ones. The figures for the number of projects and for the resulting CERs are derived from the *project design documents* (PDDs) and the UNEP Risoe Center CDM Pipeline database [4,5]. It can be seen that RES projects represent approximately 65% of all projects in the pipeline, whereas the share of emission cuts is about 47%. Wind electricity generation represents 18.3% of the total number of expected projects. In July 2010, a total of 974 wind energy projects were in the CDM pipeline, 368 of which (representing an installed capacity of 16.7 GW) were already registered.

The distribution of wind CDM projects among hosting countries, as presented in Table 3, shows that the top wind CDM hosting countries are China and India. In China, there are already 225 registered projects, of almost 12 GW installed capacity, and approximately twice more are in the process of registration. India hosts 104 registered projects, which correspond to an installed capacity of about 2.5 GW. Latin America is also a region where a considerable amount of projects is under implementation, with Brazil and Mexico being the major hosting countries. In Africa, on the other hand, there are only 4 registered projects.

The data presented in Tables 1 and 3 reveal that the CDM plays a quite significant role in the overall development of wind energy in developing countries. In China, the installed capacity of registered wind CDM projects represents half of the national total installed wind capacity (25.1 GW), and there is a large amount of projects, (about 18 GW) that are in the process of registration as CDM. In India, the registered projects (2.48 GW) represent 23% of the total installed wind capacity (10.9 GW), whereas a large amount of projects, (about 5.4 GW) is in the process of registration. It should be mentioned that some difficulties in comparing figures occur since some projects are only under construction and waiting for CDM registration, while others are already operating and are still waiting for registration. In general, the registration process is a very time-consuming procedure [6]. The process of projects' development is often supported by investing countries, which are actually buying future CERs. The relative share of investing countries to the total number of registered CDM projects is presented in Fig. 2.

Most investing countries are European, with the exception of Japan and Canada. It should be noted that these figures reflect the countries that are indicated as buyers in the information provided by the PDDs, and that, for a single project, more than one country may be indicated as buyer.

The above data clearly illustrate that China and India are very attractive as hosting countries for wind energy projects. A deeper analysis reveals significant differences in the scale of the projects realized in each country. Fig. 3 shows the classification of the 329

Table 2
RES projects in CDM pipeline [5].

Types of CDM projects by status	At validation		Requesting registration		Registered		Total expected			
Type (rejected projects excluded)	Number	kCERs	Number	kCERs	Number	kCERs	Number		kCERs	
Biomass energy	388	27,124	12	807	288	16,637	688	13.0%	44567.3	6%
Geothermal	4	320	2	1198	9	1835	15	0.3%	3352.8	0.45%
Hydro	763	96,396	50	4219	641	61,496	1454	27.4%	162110.9	21.9%
Landfill gas	147	16,506	7	563	161	28,223	315	5.9%	45292.1	6.1%
Solar	30	649	0	0	22	467	52	1.0%	1115.5	0.15%
Tidal	0	0	0	0	1	315	1	0.0%	315.4	0.0%
Wind	553	47,583	53	7869	368	35,963	974	18.3%	91414.9	12.4%
Total RES CDM	1885	188,578	124	14,655	1490	144,936	3499	65.9%	348169	47.1%
Total CDM	2879	340,221	171	29,791	2262	369,627	5312	100%	739640	100%

Table 3
Distribution of wind CDM projects among hosting countries.

Hosting country	Projects in CDM pipeline		Registered CDM projects	
	Number	MW	Number	MW
China	555	30,026	225	11,929
India	456	7841	104	2480
Latin America[a]	50	3368	21	1615
Africa[b]	13	1222	4	270
Others[c]	29	827	14	390
Totals	1103	43,283	368	16,684

Source: Own elaboration on the basis of UNEP Risoe CDM/JI pipeline analysis and database. To the state of August 1st, 2010 from UNFCCC CDM database

[a] Mexico, Brazil, Argentina, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Jamaica, Nicaragua, Panama.

[b] Egypt, Morocco.

[c] South Korea, Cyprus, Israel, Philippines, Viet Nam, Mongolia, Sri Lanka, Thailand.

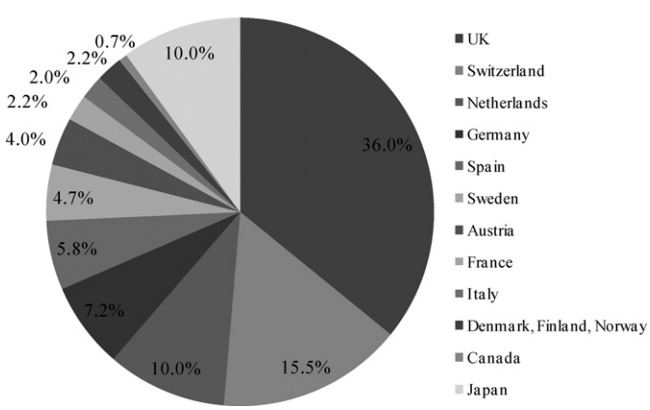


Fig. 2. Projects by investing country [4,5].

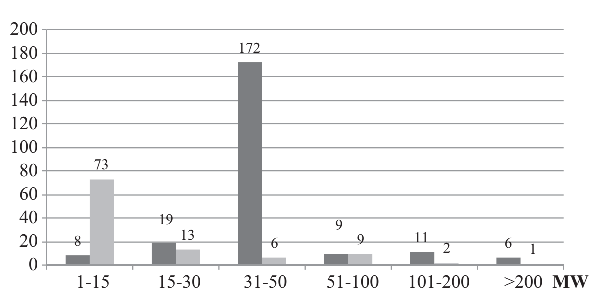


Fig. 3. Distribution of projects by installed capacity in China and India [4].

registered projects in China and India in major groups according to their installed capacity.

It can be seen that most of the registered wind CDM projects in India are small-scale (i.e. under 15MW), actually 73 out of 104. In China, most of the projects are large-scale, with the largest share of projects above 30 MW of installed capacity, and only 8 being small-scale.

Another feature of Indian projects is the fact, that many of them are bundled, i.e. several projects are considered as one activity. Among the main reasons is the reduction of CDM registration expenses and transaction costs which are relatively high, especially for the small projects.

An additional tool which helps to define the performance of all the sustainability compounds of the GHG reductions project is the Gold Standard certification. The Standard does not say that other projects are bad, but it provides assistance in search of projects that bring most of sustainability benefits. It is noteworthy, that most of wind CDM Gold Standard projects are in China (24). On the contrary, in India there is only one (out of 104 in total) [5,7].

3. Support policies for RES in developing countries

The process of wind power project development and the selection of the site need to take into account many factors, such as the wind potential, the land availability, access, and grid infrastructure. Moreover, the size of a wind farm is often determined with respect to a number of constraints, namely: financing, planning legislation, local and national development plans and policies, present and future structure of the power system, conditions in the local electricity market, and environmental impacts [8].

The major wind CDM hosting countries, namely China and India, are both very big countries presenting many interesting investment opportunities in different regions. Apart from physical factors, they have both adopted during the last years specific policy measures in order to attract investments in RES. Their example is followed by other developing countries all over the world as shortly described in the following paragraphs.

3.1. China

In China, great attention is paid to RES development. The country is endowed with large wind resources in the north, from Xinjiang Autonomous Region through Gansu Province to Inner Mongolia Autonomous Region, and in the southeast, along the coastline [9].

The Renewable Energy Law (2005) is the main framework for renewable energy policy in China enforced with a range of subsequent regulations. This law is designed to "promote the development and utilization of renewable energy, improve the energy structure, diversify energy supplies, safeguard energy security, protect the environment, and realize the sustainable development of the economy and society" (Article 1) [4,10,11]. Further, China adopted several ambitious targets for the penetration of RES in the national energy mix in order to counter balance the extensive use of coal.

Reduced value-added tax (VAT) and income tax are an essential part of supportive incentives. The regular VAT for a company in China is 17%, while VAT for companies in the renewable energy industry is: 0% for ethanol production, 6.5% for small hydropower (<25 MW), 8.5% for wind power, and 13% for biogas. The income tax on revenues from wind power generation is also reduced from 33% to 15% [10,11]. Fiscal incentives to promote renewable energy are limited and vary from province to province [9]. For renewable energy CDM projects, these tax incentives are taken into consideration for the investment return calculations in PDDs. The tax rate on CER transfer revenues from RES projects is only 2%, whereas the same rate is e.g. 30% for revenues resulting from nitrous oxide (N_2O) projects, and 65% for HFC and PerFluoroCarbon (PFC) projects [4]. Hence, it is not surprising that the adopted framework led to the fact, that near three quarters of Chinese CDM projects are in the domain of renewables.

Finally, in 2009, the Chinese government introduced a feed-in tariff for wind power, which applies for the entire operational period of a wind farm (20 years). There are four different categories of tariffs depending on a region's wind resources, ranging from 0.51 RMB/kWh (US$ 7.6 cents) to 0.61 RMB/kWh (US$ 9.1 cents). This is considerably higher than the tariff for coal-based electricity. This was an important gap to overcome. In the past, each power purchase agreement had to be negotiated individually. The power purchase price varied greatly from province to province and sometimes within the province [1,4,9].

The Chinese government also launched a programme for wind concessions as an effort to develop large-scale wind farms. The main idea lies in a tendering procedure which invites domestic and international investors to develop large-scale (100 MW) wind farms in pre-selected sites. It must be mentioned that every project has to be at least 51% Chinese-owned, in order to be qualified as a CDM activity. As a result, the control of the projects belongs to the Chinese partners [9,12]. But it was not the only incentive of domestic support. In 2004, when most of wind turbines in the Chinese market were imported, the 70% local content requirement was introduced. It was abolished in 2009. During this time, the domestic wind turbine manufacturing industry became the world's largest. By the end of 2009, there were almost 80 wind turbine manufacturers in China. The three largest domestic manufacturers (Sinovel, Goldwind and Dongfang) have a combined production capacity of 8.2 GW for an annual market of 13.8 GW [1].

3.2. India

India also adopted a range of legislative motivations for RES. The main incentives for the investment support include measures such as 80% accelerated depreciation, tax reductions for power generation projects, and direct financial subsidies for building renewable energy generating capacity. All the aforementioned measures may be coupled with concessional customs and excise duty and other incentives encouraging foreign investment procedures. In addition, a 5-year tax gratis is also provided for power generation projects using RES. The Ministry of New and Renewable Sources of India (MNRES) drafted the Renewable Energy Policy, which aims to ensure that renewable energy technologies will account for 10% of total power generation capacity in India by 2012 [13]. In order to reach this target, the state utilities encourage renewable energy development by offering remunerative price for power purchase, and also providing facilities for banking. Special sets of measures are offered to small-scale industries, when a range of local restrictions are mandatory and apply for large industries. In India there is no universal approach towards the feed-in tariff, as the local electricity regulatory commissions adopt separate tariff for different renewable sources.

Public enterprises, such as the Indian Renewable Energy Development Agency (IREDA), provide the institutional support for companies setting-up renewable energy projects. The IREDA provides concessional loans; the current interest rates are 9.5% for a maximum repayment period of 10 years and 9.0% for a maximum repayment period of 8 years [4,14]. As a result, numerous wind projects are undertaken by industrial consumers in order to displace the relatively expensive electricity from the grid.

Due to steadily growing local market, 16 companies now manufacture wind turbines in India, with an annual production capacity of 3000–3500 MW. Many of them are international companies that have set up production facilities in India, including Enercon, Suzlon, Vestas, GE, Gamesa, Siemens, WinWinD, and others [1].

3.3. Mexico

Mexico is famous for its wind potential in Oaxaca, Baja California, Tamaulipas, Yucatán, Veracruz, Zacatecas, Hidalgo and Sinaloa states. The total installed wind power capacity now amounts to 202 MW. Despite significant potential, wind development in Mexico has been slow, mainly due to the lack of adequate financial incentives for RES, issues with the existing regulatory framework and a lack of policies to encourage use of wind energy. Recent increase in installed capacity was the result of two private self-supply projects: "Parques Ecologicos de Mexico" (79.9 MW) and the first phase of the "Eurus" project (37.5 MW). However, in 2009, new laws and regulations were introduced to boost renewable energy development, and more than 560 MW of wind projects are currently under construction, of which 8 are CDM projects [1,4].

3.4. South Korea

South Korea is very dependent from fossil fuel imports. In order to diversify its energy supply, the Korean government set a goal of increasing the country's share of renewable energy in total energy supply. A report by the International Energy Agency concluded that the country could generate as much as 30% of its electricity from renewable energy sources. However, the proportion of renewable power stood at only 2.3% in 2007. The priority areas for achieving the target of 30% are photovoltaic's (PV) and wind energy (with the target of 2250 MW by 2012). For the time of publication, there were 8 registered wind CDM projects in South Korea.

Since the feed-in-tariff system for RE-generated electricity took effect in May 2002, private investors have been the driving force behind the installation of commercial wind power generators. In order to secure private investment, an application period for the base price was established as a guarantee. At present, four domestic manufacturers are developing wind power generators with capacities of 2–3 MW [9,15].

3.5. Brazil

From 2002 the "Programa de Incentivo às Fontes Alternativas de Energia Elétrica" (PROINFA) is under implementation in Brazil. This program is aimed to boost the uptake of renewable energy sources in the Brazilian electricity mix, and to increase the share of renewable energy to 10% of Brazil's electricity supply by 2020. In this light, the interactions between the dominating hydro power generation and wind generation brings many advantages. As a result, wind projects awarded through the PROINFA programme account for over 95% of wind power installations in Brazil [1].

In December 2009, the Brazilian energy regulator, Agencia Nacional de Energia Eletrica (ANEEL), hosted the country's first wind-only auction. Through that auction, 71 wind energy projects were contracted for a total capacity of 1800 MW. During the auction, the price dropped from established ceiling of R$189/MWh (102US$) to R$148/MWh (84.06US$). While the price achieved may well make wind power in Brazil less profitable than some may have hoped, the sheer volume of the auctioned capacity also shows that the Brazilian wind market is very promising [1].

There have been additional positive signs for the wind industry, with some Federal and State Tax relief designed to stimulate investment, including moves to eliminate import taxes for wind equipment, as well as the state and municipal tax on circulation of goods and services between jurisdictions [1].

3.6. Chile

The first steps to encourage greater development in clean energy production were taken in the last few years in Chile. Actually, in order to develop other than hydro (both small and large scale hydro represented 38% of total installed electricity capacity in 2007) renewable energy sources, the term "clean energy" is used. In 2007 biomass energy generation was 2% and wind generation – only 0.1% (20 MW) of national installed capacity (12,847 MW). In the north and centre of the country, there are photovoltaic solar energy projects, developed by a rural electricity supply scheme without connection to the national grid. The government objective is to establish conditions to attract investment in clean energy projects by encouraging market development through removing the main entry barriers. The electricity grid is totally private owned and concentrated what creates an entry barrier to new and small-scale energy producers. The local government works upon regulations, removal of barriers and development of support instruments, such as: program of pre-investment for advanced studies for clean energy sources, low-interest loans for renewable energy investment, capital guarantee and risk capital funds for clean energy and energy efficiency activities [16]. Adopted legislation creates a demand for clean energy within the electricity sector by setting a minimum participation quota (5% from 2010 rising to 10% by 2024). In addition, during the Copenhagen Summit in December 2009, the Chilean government made a unilateral voluntary commitment to reduce CO_2 emissions by 20% by 2020, 18% of which is based on implementation of the Renewable Energy Law and measures to improve energy efficiency.

3.7. Egypt

Traditionally reliant on available fossil fuel, Egypt tries to phase out subsidies on oil and gas, and privatize electricity production and distribution to encourage investment in RES. It has also reduced taxes on imported renewable energy equipment such as wind turbines, and established a fund to help offset the marginal costs of deploying these technologies [1,9]. For RES development support, Egypt makes the emphasis on feed-in tariffs. The objective of the policy measures is to make the sector more profitable and less reliant on carbon credits. This is expected to attract private investments in wind power sector. In 2008, the Egyptian Supreme Council of Energy approved an ambitious plan to produce 20% of total electricity from renewable energy sources by 2020, including a 12% contribution from wind energy, which is estimated to reach more than 7200MW. The plan gives enough room for private investors to play a major role in realizing this goal.

3.8. Morocco

In Morocco, the adopted National Programme for the Development of Renewable Energies and Energy Efficiency (PNDEREE) aims to increase the contribution of renewable energy to 18% of the national electricity consumption (up from 7.9%) and 10% of primary energy (up from 3.4.%) by 2012. This translates into 1564 MW of wind power development since the launch of the program in 2006. Moreover, the Moroccan government launched the so-called "EnergiPro" initiative, encouraging industrial players to reduce their production costs by producing their own energy for up to 50 MW of installed capacity. Currently, the country is well on track to meeting its target by 2012, mainly due to plans by industrial companies to install around 1000 MW of wind energy for their own consumption [1]. The private sector is expected to play a major role in this process both until 2012 and 2020. As for CDM assistance, there are only 2 registered wind power projects, which were among the first in CDM pipeline [4].

4. Contribution of CDM to wind projects' profitability

The analysis of profitability is concentrated only on projects from China and India. The share of wind CDM projects from other countries is very small and the information is limited for detailed elaboration. In order to assess the influence of CDM to the wind projects, we exploit the available information provided in the PDDs.

Wind projects recognized as CDM activities enjoy an additional financial assistance due to the profits from CERs. In the process of CDM financial analysis, project's *internal rate of return* (IRR) is often compared to the local benchmarks, which differ from country to country. The values of a benchmark first of all depend on the applied discount and interest rates. Low financial profitability compared to the benchmark values are expected to increase in case of the registration of project as CDM. China adopted a benchmark financial rate (IRR) of 8% which is said to be the official rate to assess total investments in power industries. For India, the corresponding IRR benchmark is 16% [4,17]. It should be noted that project developers have been using different methodologies and approaches for the preparation of the PDDs. The crediting period of the CDM project that is used in PDDs may be either a 7-year renewable crediting period which allows updating the data used in setting the baseline, or a simple 10-year period which provides certainty to the project developer for longer period. The 7-year crediting period may be renewed for 2 more periods, in other words, can be used for 21 years in total.

As it was also observed by other researchers the non uniformity of data from many PDDs creates difficulties in projects' comparisons [11,18]. The PDDs of Chinese and Indian projects usually contain more rich information compared with the PDDs of other countries. Unfortunately, extended investment analysis is not always provided, and even those that include such an analysis do not always provide the necessary information to check the reliability of the presented results. The sensitivity analysis, if provided, is rather helpful for better understanding the assumptions. In addition, the assumed price for CERs greatly varies.

It is observed that in most Chinese wind projects, a 7-year renewable crediting period is chosen, which leads to the assumption of a 21-year project's life. In India, the 10-year crediting period is the most preferred, although PDDs assume often longer operation periods.

Profitability indicators present also big differences not only from country to country, but also within the same country. In Chinese PDDs, the 8% financial benchmark lies in between the mean value without CERs (6.3%) and the mean value including incomes from CERs (9.1%). As we can see, the variability of the IRR is quite low. These calculations are an important part of "additionality conditions", which means that the project would not have been realized outside the CDM. In Indian PDDs, similar observations can be made, though with different benchmarks.

In general, according to the information provided in PDDs, the impact of the CER revenues on the IRR of a wind power project is relatively small, and in many cases almost marginal to reach the benchmark. Also, in some cases, different assumptions for the CER price are made in a rather ambiguous and arbitrary way, and actually these assumptions are very critical on whether the IRR will reach and overpass the benchmark or not [19].

It is clear, that besides the IRR benchmark and the assumed CER price, the real profitability of a wind energy project and the particular contribution of CDM, depends on country-specific characteristics, namely on the current electricity tariffs and the baseline emissions, determining the number of CERs issued. It must be noticed that these characteristics may differ from region to region in the same country. Besides, as it is already mentioned, a great amount of PDDs do not present this kind of financial details but only the resulting CERs. For these reasons, we preferred to base our analysis only on the contribution of CER revenues in the investment cost, which does not practically depend on the specific country and region characteristics.

Specifically, for the examined projects we use the information for the investment cost and the resulting annual CERs during the commission period. Dividing the Net Present Value (NPV) of the income from CERs in the commissioning period with the investment cost we create a Benefit/Cost (B/C) ratio which is characteristic for each project, named B_{CER}/C ratio. The price of the CERs is not fixed, that is why we use several prices performing an extensive sensitivity analysis. We must always keep in mind that the B_{CER}/C ratio does not include the additional costs and the income from selling electricity due to lack of information. Although, the investment cost represents the main cost component for wind energy projects, there are also operational and maintenance costs, as well as additional expenses related with registration and transaction costs, taxation, education of staff, etc. that although relatively low, are of course not negligible in practice.

Thus, the B_{CER}/C ratio is indicative contribution provided by CDM, while the actual B/C ratio of the project should take in account on the one side the additional income from the sales of the produced electricity, and on the other side the relatively lower operational and maintenance costs. The analysis takes into account only the Chinese and Indian projects, for which the relevant data are provided in their PDDs.

As it was mentioned before, there are preferences for carbon crediting periods between countries. Most of Chinese projects are large scale and choose the renewable crediting period, considering the option to sell carbon allowances during the whole commissioning period of the wind farm. But the renewal procedure requires additional expences and is not very attractive for small-scale projects. And there is no full certainty, that the result of the reviewing process will be positive. That is exactly the case of India, where small-scale projects are dominating and 10-year crediting period is chosen for the majority of the projects. Actually, this fact creates some difficulties in projects' comparison. Because

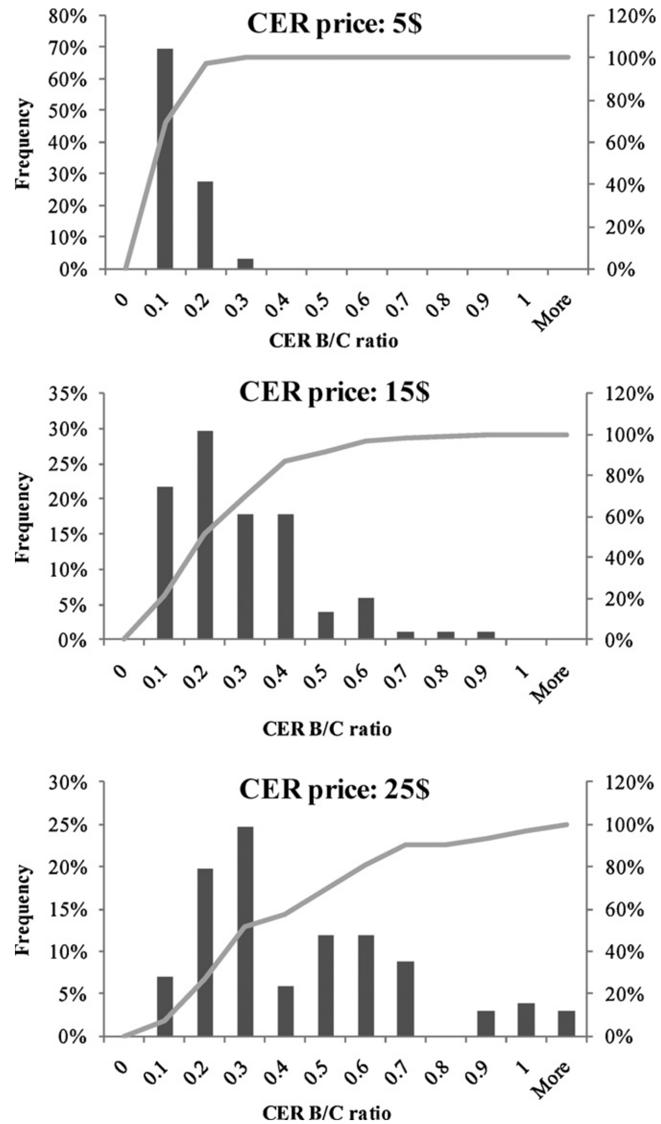


Fig. 4. The distributions of B_{CER}/C ratio based on 101 projects from China with different CER prices.

of the above mentioned reasons, we used 21 years in the NPV calculations for those projects (which indicate a renewable crediting period) and 10 years for the rest.

Regarding the CER price we considered 3 scenarios for the CER price, namely 5, 15 and 25US$. In our assumptions we keep the CER price stable at the level of the price scenario for the whole timeperiod. The actual increase of price may be counterbalanced in future by the decrease of issued certificates. Further we assume 21 years of project life for renewable crediting period with the decrease of expected CERs by 20% with each renewal procedure, mainly due to technology improvement (i.e. less polluting technologies are considered in the future baseline scenario). For those projects with 10-year crediting period, we assume only one crediting period, even if the lifetime of the project is expected to be longer. In order to calculate the required NPV from the CER income we assume discount rates equal to the benchmarks for the two countries, namely 8% for Chinese and 16% for Indian projects.

The obtained results are shown in Fig. 4 for China and Fig. 5 for India in the form of histograms. In this way the distribution of the B_{CER}/C ratios is depicted along with the corresponding cumulative distribution (continuous increasing line referring to the right axis). In order to calculate these distributions we used the projects from

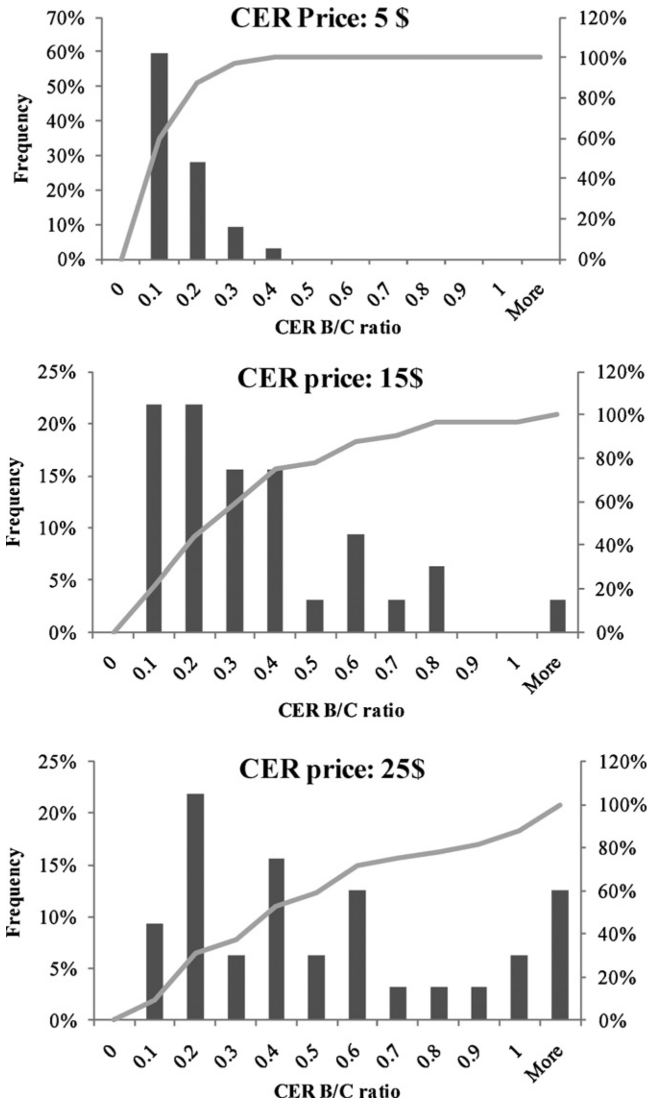


Fig. 5. The distributions of B_{CER}/C ratio based 32 projects from India with different CER prices.

PDDs database that provide the required information (investment cost, commissioning period, annual CERs) which means that we used 101 projects (from the whole of 225) for China and 32 projects (from the whole of 104) for India.

It can be seen that for the low CER price, 5US$, the CDM revenues, represent a small portion of total investment cost that is well below 30% for all projects. This means that electricity tariffs should be sufficiently high in order to make the project profitable. For Indian projects, we observe a better behavior. But in this case we have to remember that many projects are small scale and apply for a single 10-year crediting period. In other words, they need higher level of investments return because the great majority of the projects applied for shorter crediting period (10 years instead of 21).

With the price of 15US$, which is close to actual prices, the situation is better. For more than half of projects, the incomes from CER sales may consist near half of initial investments. But the projects are still strongly relying on electricity sales. This is hard in conditions where electricity from fossil fuel costs much less, than from renewables. Worth to mention, that some Indian projects may cover investments only with CER incomes.

On the other side, at a CER price of 25US$, the incomes may counterbalance the greatest part of the annualized projects' investments even without taking into account the electricity sales. Almost 30% of the projects from China and 40% of the projects from India present a B_{CER}/C ratio more than 0.5. The distribution of the B_{CER}/C ratio is close to be uniform with the cumulative distribution being almost linear. This means that the differentiation among the projects regarding their B_{CER}/C ratio increases as the CER price also increases.

Comparing the three scenarios for CER price, we can observe that as the price increases, the differentiation of CDM projects regarding the beneficial impact of CDM (B_{CER}/C ratio) also increases. The distribution of the B_{CER}/C ratios is gradually transformed from log normal (low CER prices) to uniform (high CER prices).

In the most likely scenario with the CER price at 15US$ the percentage of projects with B_{CER}/C ratio more than 0.5 is almost 10% for China and almost 20% for India. These percentages are going to 0% for a CER price 5US$ and increase to 30% and 40% for 25US$. However it is noteworthy that for higher CER prices there are projects from both countries (3 from China and 4 from India) that reimburse the investment cost with just the income from CERs (B_{CER}/C ratio > 1).

Conclusively, we observed a great variation regarding the economic effectiveness of CDM projects. High CER prices (e.g. 25US$) must be defined in order to obtain good signs for the return on investment for the CDM projects. Under the current relatively low CER prices, CDM cannot guarantee a high attractiveness of wind energy projects, unless in very favorable conditions of high wind speeds and high electricity tariffs. And this is an indication that, under the current conditions, the most critical factor for investing in wind power plants is rather the framework of the country towards such investments, than the financial assistance from CER revenues.

5. Conclusions

Wind energy is the power generation technology that can assist to make the necessary cuts in GHG emissions in the critical period up to 2020. In developed countries, wind electricity generation is a fast growing industry, whereas, in developing countries, it still faces a lack of economic competitiveness towards conventional technologies. Moreover, the lack of long-term price stability is one factor inhibiting the possibility of long-term contracts, particularly in the case of wind-power projects, due to their low capacity factor. Moreover, project developers face the lack of basic technical studies regarding wind and sun availability in many developing countries. This needs additional time to perform these studies by their own expenses and postpones the implementation of projects. The access to the transmission lines and networks often is a crucial factor.

During the last years, CDM became the most famous international mechanism, which helps to attract investments in developing countries under the goal of tackling climate change. RES technologies make the largest part of these projects. CDM provides assistance for wind technologies and is an ancillary source to defray the marginal costs of wind power versus conventional fossil fuel plants.

In addition, with simple, straightforward calculations, and for low CER prices, we observed that the influence of CER revenues is not as significant as one would expect, unless they are combined with low discount rates. Also with low discount rates the environment for long-term investments is friendlier than in case of high ones. In case of high prices, the influence could be very significant and even reach the level of annualized investments, but such levels of prices have not been observed so far. The uncertainty of future prices, combined with the overall uncertainties of a wind power plant investment plays a negative role in the promotion of wind technology in developing countries.

In our study, and in the case of the major hosting countries, namely China and India, we confirmed that a key factor for the development of CDM projects is the political and legal framework.

This is also verified by the fact that these two countries have a large amount of wind installations that are not CDM projects. Other countries like Egypt develop the RES support policy measures in a way, that activities become less reliant on carbon credits. Generally, the possibility of CER incomes, the access to the grid, and the local stakeholders appear as secondary decision factors.

It was also observed that even in the same country, the behavior of the projects regarding the benefits from the CDM varies significantly. This observation is reinforced as the price of CER increases.

For countries other than China and India, a fast development of wind electricity generation is not observed, despite the fact that there exists a considerable wind potential. This may be due to the fact that CDM does not provide the adequate incentives for investments in wind power plants unless a favorable framework already exists. This observation does not imply that CDM is not achieving its original purpose. However, it does imply that countries should create a favorable framework in order to attract wind power plant investments, and also have the benefits from carbon credits sales. For many developing countries CDM has not acted as a strong financial incentive in wind electricity generation for private companies.

In addition, the clarification and simplification of the carbon finance mechanisms can assist in a broader participation of developing countries in the carbon finance market. This assistance can be increased through more timely work of all the bodies involved in the CDM development and registration process and through the creation of friendlier environment by the local governments.

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